ISSUE DOCUMENTATION – RTCA SC-186

ASA / ASAS

Tracking Information (committee secretary only)	
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Short Title for Change Issue:	Need for Velocity Lag Indicator to Better Characterize State Quality During Maneuvers

Topic:	X	ASA	X	High-level		ASAS		STP		ASSAP		CDTI

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Table/Figure number(s)		Other	

Proposed Rationale for Consideration (originator should check all that apply):	
	Item needed to coordinate with other documents
X	ASA MASPS
	1090 MHz Link MOPS
	UAT Link MOPS
X	TIS-B MASPS
	Previously written CDTI MOPS
	Other (include document title):
X	Item needed for harmonization with international requirements
X	Item identified during recent ADS-B development activities and operational evaluations
	MOPS clarifications and correction item
	Validation/modification of questioned MOPS requirement item
	Military use provision item
X	New requirement item

Nature of Issue:		Editorial		Clarity		Performance		Functional

Issue Description (attach additional sheets if necessary):

The current formulation of NIC and NACp quality metrics for ADS-B and TIS-B broadcast positions was primarily based on the quality of sensed position measurements. Recent investigations have focused on the quality of velocity data as well, since velocity extrapolation is often required to translate position measurements to the effective time-of-applicability of ADS-B broadcasts. However, the current NACv metric for assessing velocity uncertainty is not sufficient to characterize velocity error under aircraft maneuver conditions. One means of accommodating such increased uncertainty is to degrade NIC, NACp and NACv based on worst-case assumptions that the aircraft is executing a large turn maneuver. This issue paper introduces another potential means of characterizing velocity error in terms of a velocity lag indicator or velocity latency of the transmitted velocity vector, including any tracker or processing lag in creating the transmitted velocity, as well as the usual time lag from the time-of-position measurement to the time of applicability of the transmitted position vector.

There are several sources of ADS-B / TIS-B data that do not measure velocity directly. In such cases, as with classic radar processing, a data tracker is needed to create a velocity estimate on the basis of past measurements of position data. Typically the data tracker is optimized to achieve a trade-off between accuracy or precision of steady state tracking (as characterized by the NACv metric), and the response time to track a maneuvering target. The latter metric can be characterized by a velocity tracker lag that is only dependent on the weighting of past measurement data, and is not an explicit function of the aircraft maneuver, i.e. if an aircraft is in a turning maneuver with an average 2 deg/sec turn rate and the tracker has

a velocity lag of 10 seconds, then the heading error is on the order of 2 deg/sec* 10 sec = 20 degrees heading error after 10 seconds of turn maneuver. The combination of steady state velocity accuracy and tracker lag are adequate to characterize the surveillance performance of such systems to first order, whereas velocity accuracy alone only characterizes surveillance performance during non-maneuver periods. It is possible, for example that a radar system or a back-up source of ADS-B position such as dual DME could exhibit steady state characteristics that are consistent with medium-high surveillance quality, e.g. NACp>=7, but would deliver significantly lower quality position estimates, whenever the target aircraft maneuvers due to large tracker lag plus transmit system latencies.

Some means of indicating the size of such velocity latencies is needed in order to properly characterize ADS-B sources according to both accuracy and system responsiveness during maneuvers. In the case of a modern multi-sensor system such as ASDE-X multi-lateration, or the use of Dual DME and INS processing in a Complementary Filter, tracker lags can be minimized by proper data processing. Such modern navigation / surveillance systems should not be penalized based on the capabilities of lower end (classic) Radar and Navigation Data Processing systems. This can be achieved by broadcasting (one or two bit) velocity lag data, and limiting the functional use of applications with inappropriate lag characteristics.

Originator's proposed resolution if any (attach additional sheets if necessary):

The author proposes two alternative means of specifying velocity lag for ADS-B and TIS-B systems. The first proposal is a one-bit velocity indicator flag that gives a coarse indication of systems with large tracker lags as can be expected from classic radar processing systems as the basis for TIS-B reports. The proposed definition of the one-bit velocity lag indicator (for ADS-B /TIS-B broadcast in the Mode Status field) is

VLAG = 0 Unknown velocity lag or lag > 12 sec
1 Velocity lag < 12 sec,

where velocity lag is the sum of the tracker or processing lag in the velocity estimate at the position measurement time plus the transmit latency from the position measurement time to the time-of-applicability of the transmitted position vector (assuming no latency compensation in the velocity estimate). The one-bit velocity lag indicator is primarily meant as a means of indicating those systems that are not appropriate for applications that are intended for use during maneuver periods as well as non-maneuver periods, e.g. conflict detection. Even display of a velocity trend vector can be highly misleading for systems with large velocity lag during maneuver periods. Applications such as Enhanced Visual Approaches that are intended for non-maneuver periods only may be able to use systems with VLAG=0. (The reason for 12 seconds as the proposed threshold is that an aircraft in a 3 deg/sec turn maneuver can have a heading error of at most 36 degrees = 3 deg/sec*12 sec, which is probably marginal for tracking and displaying a maneuvering target, i.e. heading errors larger than 30 to 40 degrees may be misleading as to future aircraft intent.)

The proposed definition of a two-bit velocity lag indicator gives increased accuracy of velocity lag:

VLAG = 0 Unknown velocity lag or lag > 12 sec.
1 Velocity lag between 6 sec and 12 sec,
2 Velocity lag between 3 sec and 6 sec,
3 Velocity lag between 0 sec and 3 sec.

(Note: A three-bit lag indicator could be used to indicate systems with even smaller velocity lag for high accuracy TQL applications such as closely spaced parallel runway incursion monitoring.)

The two-bit definition allows for better differentiation of maneuver performance across different types of ADS-B and TIS-B systems, e.g. a TIS-B report coming from a classic radar tracker may report VLAG = 0, whereas a TIS-B rebroadcast of an ADS-B report would likely broadcast VLAG = 3, indicating a velocity lag consistent with that of the report position latency. Other TIS-B systems with PRM-like performance, and ADS-B reports from non-GPS sources could be expected to deliver VLAG values between 1 and 3. The author prefers the latter two-bit definition since it better differentiates the quality of velocity data and maneuver performance of a wide range of potential ASA sensor sources.

Justification of Proposed Resolution Method:

(1) Potential Impact of Large Maneuvers on NACp, NACv, and NIC:
Most aircraft maneuvers of interest for air traffic separation purposes induce accelerations on the order of 1 knot/sec to 10 knot/sec (for a ½ g pattern turn onto baseleg). The issue is how to accommodate position and velocity uncertainty in an ADS-B state vector broadcast that potentially could be during a maneuver period. If NACp and NACv are based on state vector measurement error only, then the actual errors can be significantly greater when maneuvering. For example, if the velocity lag in an ADS-B transmission is 5 seconds, then during a 5 knot/sec maneuver the velocity lag error is 5*5 = 25 knots (NACv=0). Should the non-maneuver velocity accuracy be used to characterize NACv, or should NACv and potentially TQL level be degraded due to the potential of a significant maneuver? It is clear that degrading quality metrics such as TQL due to a potential but unknown maneuver would compromise the potential value of ADS-B during non-maneuver periods. However, during maneuver periods some method must be used to accommodate the increased uncertainty in the position and velocity states. In some separation applications such as Conflict Detection, the indicated velocity lag will have the main effect of delaying a separation or conformance alert by the indicated lag time. This is a significant effect, but one having far less impact on separation applications than direct degradation of NACp, NACv, and NIC.

(2) Potential Impact on Computing Along Track and Cross Track Uncertainty:
It has been proposed that the parameters NACp, NACv and possibly NIC should represent non-maneuver errors and that the most significant maneuvers that could degrade state accuracy are large turn maneuvers that mainly degrade cross-track uncertainty. Although this is true for GPS based ADS-B state reports, it is not necessarily the case with TIS-B reports with large tracker lags, i.e. in the latter case both along track errors and cross track errors are significantly degraded if the tracker lag exceeds 10 to 15 seconds, since this induces a large heading error in the along track direction. The broadcast of a one or two bit velocity lag indicator is essential to differentiate between these cases, and to properly accommodate maneuver induced error uncertainty. If the proposal to compute cross track uncertainty on the ASSAP / receive side is accepted, then it is essential that sufficient information be transmitted, such as presence of large velocity lags, in order to perform these calculations correctly in both circumstances, i.e. relatively small velocity lags and very large lags.

Other Issues:

- *Guidance for Creating VLAG indicator for representative TIS-B and ADS-B systems:*

- For GPS based ADS-B systems, VLAG is compatible with position latency, i.e. if position extrapolation by 2.3 seconds is needed to obtain the position state at the TOA, then VLAG =3 (for the two-bit definition.)

- For non-GPS based ADS-B systems, VLAG is compatible with position latency for FMS based systems that use INS complementary filters or equivalent. For systems that simply differentiate position to get velocity (typically using an alpha-beta filter), VLAG is the sum of the tracker lag and the position latency to TOA.
- For classic single-sensor radar tracking based TIS-B systems, VLAG is the sum of the tracker lag currently in use (Non-maneuver or Maneuver filter) and the time latency to TOA.
- For TIS-B rebroadcast systems, VLAG is based on the value received from the ADS-B system, since rebroadcast will add at most one second to the velocity lag.

- *Backward Compatibility with earlier MASPS and MOPS*
For earlier version # systems, default VLAG =0 and interpret the flag as velocity lag > 12 sec. for TIS-B systems, and velocity lag between 3 and 6 s for ADS-B systems with TQL > 0 (based on ASA MASPS requirements (Table 2-3) for position latency).

- *Other Alternatives,*

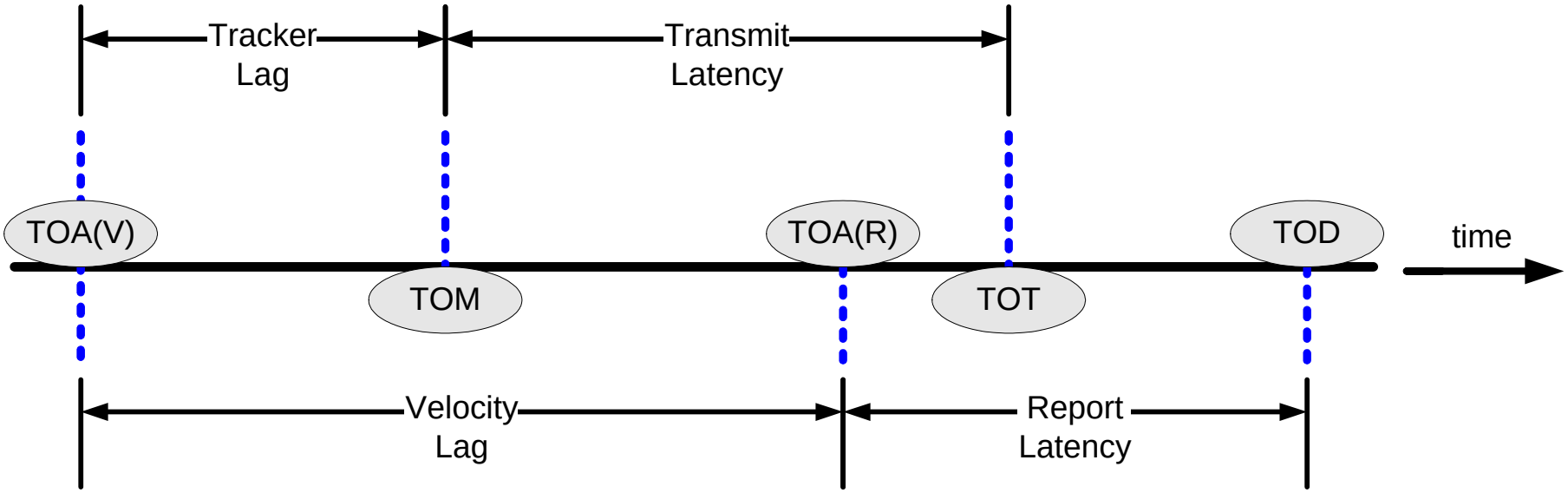
Use velocity lag as an additional row in the TQL table and avoid explicit broadcast of VLAG.

WG4 Deliberations (21 July 2004):

Tony Warren briefed a joint session of the STP and ASSAP sub-groups of WG4 ASAS MOPS. The briefing summarized the points raised in the preceding sections of this Issue Paper.

Four conclusions came out of the discussion that followed:

- There is a need to analyze the impact of relaxing the NACv requirement for the CD application (specified in Table 2-3 of DO-289). Jonathan Hammer agreed to lead this action and report back to WG4.
- Tony had a slide in his briefing that the members of WG4 in attendance felt did a good job of describing several important time reference points for ADS-B data. The definitions and terms he used will be folded into the ASAS MOPS. Figure 1 at the end of this paper shows the slide in a slightly reformatted version.
- There will be an Issue Paper created about Velocity Lag to WG4. This issue paper will be considered for the next revision of the ASA MASPS.
- The ASAS MOPS document will move forward without incorporating Tony's proposal about VLAG into the document.



TOA(V)	Time of Applicability of Velocity Vector
TOM	Time of Measurement (Position Vector Update)
TOA(R)	Time of Applicability of ADS-B Report
TOT	Time of Transmission of ADS-B Message
TOD	Time of Delivery of ADS-B Report to ASSAP